Survey of Northern Abalone, *Haliotis kamtschatkana*, Population in Queen Charlotte Strait, British Columbia, May 2009

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ABSTRACT

Lessard, J., and Egli, T.P. 2011. Survey of northern abalone, *Haliotis kamtschatkana*, population in Queen Charlotte Strait, British Columbia, May 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2959: iv + 17 p.

In May 2009, selected sites in Queen Charlotte Strait were surveyed to examine changes in wild northern abalone, *Haliotis kamtschatkana*, population. Approximately half the sites had been previously surveyed in May 2004. A total of 54 abalone were found at 14 of the 34 (41%) sites surveyed. Mean shell length (SL) was 78.7± 2.6 mm and 18.5% of the individuals were large adult size (≥100 mm SL). The mean size did not change significantly since the last survey. The overall density of abalone was 0.109 ± 0.033 abalone/m^2. Densities of immature (< 70 mm SL), mature (≥ 70 mm SL), and large adult (≥ 100 mm SL) size classes were estimated as 0.038 ± 0.014 abalone/m^2, 0.072 ± 0.025 abalone/m^2, and 0.021 ± 0.009 abalone/m^2, respectively. While all estimated densities were higher than those found at the same sites in 2004, only the difference in large adults was statistically significant. The density estimates were still low compared to pre-fishery closure levels and suggest continued pressure on the abalone populations. Poaching, increased predation pressure from sea otters, along with low recruitment success are likely causes for the slow recovery of this species which is now listed as *endangered* by the Committee on the Status of Endangered Wildlife in Canada.

RÉSUMÉ

Lessard, J., and Egli, T.P. 2011. Survey of northern abalone, *Haliotis kamtschatkana*, population in Queen Charlotte Strait, British Columbia, May 2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 2959: iv + 17 p.

La pêche de l'ormeau nordique, *Haliotis kamtschatkana*, en Colombie-Britannique (CB) a été fermée depuis 1990 afin de protéger l'espèce. L'ormeau nordique a été classifié comme étant *menacé* en 1999 par le Comité sur Situation des Espèces en Péril au Canada, et le statut a été élevé à *en voie de disparition* en 2009. En mai 2009, un échantillonnage a été effectué dans le détroit de la Reine Charlotte pour estimer l'abondance et la distribution des ormeaux nordiques. Près de la moitié des sites avaient déjà été échantillonnés en mai 2004. Cinquante-quatre ormeaux ont été mesurés à 14 des 34 sites échantillonnés. La longueur moyenne était 78,7 ± 2,6 mm et 18,5% des ormeaux étaient de larges adultes (≥100 mm de longueur). La densité moyenne totale était 0,109 ± 0,033 ormeau/m^2, une légère augmentation comparée aux résultats de 2004. Les densités des ormeaux immatures (<70 mm), matures (≥70 mm) et large adultes ont été estimées à 0,038 ± 0,014 ormeau/m^2, 0,072 ± 0,025 ormeau/m^2, et 0,021 ± 0,009 ormeau/m^2, respectivement. Toutes ces densités étaient plus élevées que celles estimées en 2004, mais seulement celle des larges adultes était statistiquement différente. Ces densités sont basses comparées à celles trouvées dans ces zones avant la fermeture de la pêche. La prédation par les loutres de mer, le braconnage et un faible taux de recrutement sont probablement responsables du lent rétablissement des populations d'ormeaux nordiques dans le détroit de la Reine Charlotte.

INTRODUCTION

Northern abalone, *H. kamtschatkana*, are patchily distributed along exposed or semi-exposed coastlines from northern Alaska to Baja California (McLean 1966; Geiger 1999, COSEWIC 2009). Historically, abalone were an important food source for First Nations of coastal British Columbia (BC) and more recently were the target of a commercial fishery. The biology and fishery of the northern abalone have been reviewed by Sloan and Breen (1988) and Farlinger and Campbell (1992).

Index site surveys have been conducted by the Department of Fisheries and Oceans Canada (DFO) since 1978 to monitor the status of this mollusc species. Due to low population levels and rapidly declining densities, DFO prohibited the harvest of northern abalone in BC in December 1990. In 1999, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the northern abalone as *threatened* in Canada (COSEWIC 2000). Since then, little or no recovery of the wild abalone population has been observed and, in 2009, the status of northern abalone was designated to a higher risk category as *endangered* by COSEWIC (COSEWIC 2009). The continued illegal harvest of wild abalone as well as low recruitment levels are among the main threats to northern abalone recovery (DFO 2007; COSEWIC 2009). Northern abalone is legally listed and protected as *threatened* under Schedule 1 of the Species at Risk Act (SARA). The listing under SARA includes prohibitions for the killing, harming, harassing, possessing, buying or selling of an individual, or its parts (including shell), of a listed species.

As a consequence of the COSEWIC listing, a National Recovery Strategy for the Northern Abalone was prepared by DFO and the Abalone Recovery Team (Abalone Recovery Team 2004). In 2007, the strategy was expanded and revised to include specific goals for the Queen Charlotte Strait (QCS) (DFO 2007). The relevant short term objective set out in the recovery strategy was: "[to] observe that the mean total density estimates at newly established index sites in the Queen Charlotte and Johnstone Straits do not decline below the level observed in 2004 (0.06 northern abalone per m^2 and 0.02 northern abalone per m^2, respectively)".

QCS is comprised of Pacific Fisheries Management Areas 11 and 12. From 1977 until the fishery closed in 1990, 107 tonnes of abalone were harvested from this area, representing 6.3% of the total catch (Farlinger 1990). During the commercial fishery, the majority of landings were in Haida Gwaii (HG, formerly known as the Queen Charlotte Islands) and the northern coast of BC; therefore abalone assessment was conducted primarily in those areas and surveys in QCS were rare. Breen et al. (1978) provided the only survey conducted in QCS during the commercial fishery and they based site selection on information gathered from fishing logs. In 2004, DFO conducted the first systematic survey of QCS and Johnstone Strait (Davies et al. 2006). The 2004 survey included repeated sites from Breen et al. (1978), new randomly selected sites and sites within finfish aquaculture tenures.

In order to continue monitoring northern abalone populations and evaluate recovery efforts, a new survey was conducted in QCS in 2009. Objectives of the 2009 survey were two-fold: to monitor abalone abundance in QCS by estimating densities at previously surveyed index sites and to extend our knowledge of abalone abundance

and distribution in QCS by increasing the area previously surveyed. Based on recommendations from the 2004 survey, additional sites were selected to increase the extent of the surveyed area in QCS, while Johnstone Strait was not resurveyed because abalone habitat is limited there. This report presents the results of the survey in the QCS in May 2009 and compares them to the 2004 survey results.

METHODS

SURVEY METHODS

SCUBA surveys were conducted over a period of four days in May 2009. The Canadian Coast Guard research vessel *CCGS Vector* was used as the base for daily diving operations while two small boats transported the dive team to and from the survey sites. The boats were equipped with a GPS and nautical charts to confirm the location of each site.

A total of 34 sites were surveyed, including 17 sites repeated from the 2004 QCS survey and 17 additional sites which were randomly selected. None of the 36 sites surveyed in Johnstone Strait in 2004 were resurveyed on the recommendation of Davies et al. (2006), as abalone habitat in Johnstone Strait was limited. Furthermore, the finfish aquaculture sites within the previous survey were not representative of the greater area and were not resurveyed in the present study.

Random sites were selected without bias using 'Random Points along a Line', an ArcView (ESRI version 3.2) script (Eichenlaub 2000) that randomly chooses sites along the shoreline selected. For logistical purposes, the research area was sub-divided into two general survey areas. Sites located on the northern side of QCS, including those around Bramham Island, Shelter Bay and the Raynor Group were named "North Queen Charlotte Strait" (NQCS) sites (Fig. 1). Those encompassing the Gordon Islands and Walker Group were named "Gordon Channel" (GC) sites (Fig. 1). All resurveyed sites from the 2004 survey were located within the GC area. In the NQCS area, a total of 32 sites were randomly selected using the method described above. Of these, 17 sites were surveyed for abalone abundance and the remaining 15 sites were not surveyed because of time constraints or because abalone habitat was not present at the marked location.

Once at the coordinates for a given site, divers surveyed abalone habitat using the method described by Breen and Adkins (1979), commonly referred to as a 'Breen' survey. Divers began surveying by placing a 1 m^2 quadrat at the top of the abalone habitat zone; the divers surveyed 16 quadrats within a 7 m by 16 m area. The 16 quadrats were arranged in four transects, each 4m apart; and each of the four quadrats within a transect were 1m apart (i.e. every 2nd quadrat per transect). The percent cover and dominant algal species, substrate type and depth were recorded before all vegetation was cleared from the quadrats. The divers then searched for exposed abalone within the quadrat and measured the shell length (SL in mm) of individuals found. Urchins and abalone predators (such as sea star, *Pycnopodia helianthoides*, or red rock crab, *Cancer productus*) within the quadrat were also counted. If abalone were

not encountered within the first 8 quadrats surveyed, the dive was aborted and the site count was scored as zero. In four of the first eight quadrats, divers searched for cryptic abalone by turning over cobbles and boulders if possible if present. The % cover of all algae combined was recorded for each of the following categories: 1) canopy (tall shading surface reaching algae, >2m), 2) understorey (algae between 20-30cm and 2m tall), 3) turf (erect small foliose and branched species 5cm and 20-30cm tall), and 4) encrusting (species which form a thin crusty layer on rocks). The dominant algae were recorded to species for canopy and understorey. As species identification is difficult for smaller algae, only general morphology and phylum were used to identify algae for turf. No species were recorded for encrusting. O'Clair and Lindstrom (2000) was used for algal species names and descriptions.

ANALYTICAL METHODS

All recorded depths were corrected for tide height. Each site was given a slope value based on the depth range among the sampled quadrats.

Abalone and urchin densities were estimated as the number/m^2 for each site. Variation of mean density and mean size estimates are reported as ± standard error of the mean (SEM). Density estimates from the 2004 survey presented herein are different from previously published results (Davies et al. 2006) because we excluded the 2004 finfish aquaculture sites to make the 2004 results comparable to the present study.

Systat 13 was used for all statistical analyses. As the density and size frequency data were not normally distributed, the non-parametric Mann-Whitney U test was used to compare mean SL and densities between survey areas and between survey years. The 2009 mean abalone densities and mean SL were compared between GC and NQCS, whereas only data from the GC sites were used to compare changes between the two survey years. The Mann-Whitney U test was also used to compare urchin densities and algae cover between years at sites in the GC.

RESULTS

A total of 34 sites were surveyed for the presence of abalone in QCS (Fig. 1). Thirty-nine abalone were measured at GC sites and 15 at NQCS sites (Table 1). Abalone were found from 1m above Chart Datum to 6m below. In both survey areas, 41.2% of sites (7 of 17) had abalone present. A total of 23 quadrats, 21 of which were within the GC area, were searched for cryptic abalone, yielding none.

Abalone from all sites surveyed ranged in size from 34 to 107 mm (Fig. 2). The mean SL was 79.8 ± 2.9 mm at GC sites and 76.1 ± 5.6 mm at NQCS sites, a difference which is not statistically significant (Table 1). Mean abalone size did not change significantly since the 2004 survey (Table 1). The population size structure was similar between the two areas, with most measured animals (64.8%) being of mature size (≥ 70mm SL) (Table 2).

Abalone densities in GC were consistently higher for all size classes than in NQCS (Table 2). These differences were not statistically significant; however given the low

density estimates with relatively high SEM (>30% of the mean), our statistical tests have low power to detect differences. Total abalone densities were estimated to be 0.164 ± 0.061 abalone/m^2 in GC and 0.055 ± 0.020 abalone/m^2 in NQCS. Combined density from both areas was 0.109 ± 0.033 abalone/m^2. Highest densities were found for mature individuals (≥ 70 mm SL) at a combined value of 0.072 ± 0.025 abalone/m^2. Only large abalone (≥ 100 mm SL) were present in significantly higher densities than in the previous survey (Table 2). Density estimates for abalone by size category for each site surveyed are presented in Appendix 1.

Urchin densities, composed of a mixture of mostly green sea urchin, (*Strongylocentrotus droebachiensis*) with fewer red sea urchin (*S. franciscanus*), were 3.58 ± 0.87 urchins/m^2 in GC and 2.97 ± 0.66 urchins/m^2 in NQCS (Table 3). There was no significant difference in urchin densities between the NQCS and GC sites (U = 159.5, p = 0.604). The urchin density in GC estimated in 2009 was similar to the 2004 estimate of 3.62 ± 0.86 urchin/m^2 (U = 158.5, p = 0.924).

An average of 35.9 minutes (range 2 to 72 minutes) was spent diving at each site (Table 3). While the majority of sites had bedrock as the dominant substrate, more abalone were found at sites where boulder was the dominant substrate (Tables 4 and 5). There was very little soft substrate found at any of the sites (Table 4). The dominant algal species of the canopy layer was *Nereocystis leutkeana*, which was present in varying degrees at almost every site (Table 4). The composition of the understorey was more complex, with several species found in abundance. At the GC sites, *Cymathere triplicata* was most common, whereas it was almost absent at the NQCS sites where a variety of algae were found. At the turf level, articulated corallines were most abundant. A varying degree of encrusting algae was encountered at each of the sites. In GC, there was significantly more canopy cover and less turf cover in 2009 than in 2004 (Table 6). The understorey cover was also higher in 2009, though not significantly, and the encrusting cover was similar in both years.

Most sites were associated with a combination of hard substrate, presence of sea urchins, and a complex algal community. Sites R38 and R51 had little encrusting algal cover, little or no urchin and the presence of *Agarum clathratum* which is usually not exposed to waves and is an indicator of protected habitat (Druehl and Elliott 1996). The habitat found at R38 and R51 indicate that these sites are not preferred habitat of abalone (Lessard et al. 2007).

DISCUSSION

The two objectives of the 2009 survey, to monitor abalone abundance in QCS and extend our knowledge of abalone abundance and distribution in QCS, were achieved. While abalone abundance was lower in NQCS compared to GC, abalone and/or their habitat were distributed throughout the area surveyed. The mean density estimated in QCS in 2009 was higher than in 2004. At first glance, the increase in abalone density between 2004 and 2009 appear to be large, almost a 4 fold increase, yet this difference is not statistically significant. Abalone densities were at such low levels that even large relative changes in densities correspond to very small numerical differences. Consequently, in order to observe genuine evidence of recovery, the relative changes in

abalone density will have to be very large. Even if the increase in abundance was real, the estimated density of 0.109 abalone/m^2 was still low compared to the latest index site surveys in HG and along the Central Coast (CC) which had mean estimated densities of 0.43 and 0.40 abalone/m^2, respectively (Hankewich and Lessard 2008; Hankewich et al. 2008). In addition, 80.5% and 76.5% of sites had abalone present in HG and CC, compared to only 40% in QCS. Abalone density in the QCS was at a level where the possibility of recruitment failure is high (Shepherd and Brown 1993, Shepherd and Partington 1995; Babcock and Keesing, 1999; Campbell 2000). Several limiting factors have contributed to the continued low levels and/or decline in abalone populations since the fishery closure in 1990 (COSEWIC 2009). Of these, low recruitment and sea otter predation are of special concern in the QCS area.

The size and distribution of abalone populations required for effective reproduction and subsequent successful recruitment are unknown. Current knowledge of abalone, in general, suggests that there needs to be sufficient densities within patches of large mature abalone close enough together to successfully spawn and produce viable offspring (Shepherd and Brown 1993, McShane 1995, Shepherd and Partington 1995; Levitan and Sewell 1998; Babcock and Keesing, 1999). Shepherd and Partington (1995) showed that there was a critical stock density threshold (0.15-0.2/m^2) for the *H. laevigata* in Waterloo Bay, South Australia, below which the risk of recruitment failure was high. Rothaus et al. (2008) observed recruitment failure in the San Juan Islands, Washington, at levels above 0.15-0.20 abalone/m^2 and speculated that for *H. kamtschatkana*, higher densities were necessary to sustain the stocks. Furthermore, critical thresholds, whatever they may be, do not fully provide protection against recruitment failure as patch size is also important (McShane 1995). In QCS, less than 3% of quadrats had more than 1 abalone. While the number of abalone within a quadrat is not a true indication of patch size, it does provide an index of aggregation. The few small patches observed on the QCS survey could indicate an increased possibility of recruitment failure.

Sea otters (*Enhydra lutris*) were first observed in the western portion of QCS during an assessment survey in 2001 (Nichol et al. 2009). Very few otters were initially present in QCS, but their numbers have increased from 74 in 2001 to 218 in 2008 (Nichol et al. 2009). The presence of sea otter rafts defines their range in distribution. In 2008, their range did not extend into the QCS survey area, however individual sea otters were observed around surveyed sites in 2009 (J. Lessard, pers. observation) suggesting imminent range expansion and/or that sea otters foraged in the area. As an important predator of marine invertebrates including abalone, sea otters are expected to have significant effects on abalone populations in the areas they occupy (Watson 2000; Lessard et al. 2007). In BC, abalone do co-exist in areas with sea otters, but it is not known at this time if this will persist when sea otters' preferred food item, sea urchins, is depleted. Sea otters and abalone have coexisted in BC for millennia prior to the extirpation of sea otters in BC by humans (Watson 2000). However, the exact mechanisms for this coexistence and the survival of abalone at low abundance in BC are not known.

Studies have shown that abalone, in areas where sea otters are present, are restricted to crevices and other cryptic habitats where they are inaccessible or hidden

from sea otters (Lowry and Pearse 1973; Cooper et al. 1977; Pollard 1992; Watson 1993, 2000). In the present survey, more abalone were found at sites where boulders were the dominant substrate. This habitat association was also found on the north-west coast of Vancouver Island in 2008 where sea otters are also present (Hankewich and Lessard, in preparation a). In contrast, abalone were more numerous at sites dominated by bedrock during a survey in 2008 on the west side of Haida Gwaii where sea otters are absent (Hankewich and Lessard, in preparation b). Interestingly, urchin densities were similar between the 2004 and 2009 QCS survey years which may indicate low predation rates by sea otters in the area. However, because urchin species and sizes were not recorded during the abalone surveys, trends in urchin species composition or size frequencies is not known and sea otter predation effects on urchins in QCS cannot be clarified. While measuring urchins is time consuming and would greatly restrict the number of sites that could be surveyed for abalone abundance, counting urchin species separately would require minimal change in survey design and should be carried out in future abalone surveys.

The increase in kelp cover may not have been indirectly caused by the presence of sea otters in the area. Larger than usual kelp coverage was also observed along the north coast of BC, outside of the sea otter range, just days before the present survey took place (J. Lessard, pers. observation).

While the overall density of 0.109 ± 0.033 abalone/m^2 may not be sustainable, the short term objective of the recovery strategy recommending that the density of abalone at index sites in the QCS not fall below 2004 levels has been achieved (DFO 2007). This study suggests that, while low in comparison to CC and HG, abalone densities in the QCS appear to be stable at present.

Abalone populations in QCS should be assessed by continued periodic surveys of index sites to monitor any population changes. All surveyed sites with good abalone habitat should be resurveyed as per the schedule recommended in the Recovery Strategy (DFO 2007). As sea otter presence is expected to increase in QCS, cryptic searches should also continue in future surveys.

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Table 1. Abalone count, mean size, and survey effort for index sites in Queen Charlotte Strait as well as Mann-Whitney test results between survey areas and survey years. Standard errors are shown in brackets.

	Number of Sites Sampled	Number of Quadrats Sampled	Number of Quadrats searched for cryptic abalone	Total Abalone Count	Mean Size (mm)	Percent of Sites with Abalone
Gordon Channel 2004	19	191	0	13	77.7 (4.9)	26.3
Gordon Channel 2009	17	200	21	39	79.8 (2.9)	41.2
North Queen Charlotte Strait 2009	17	208	2	15	76.1 (5.6)	41.2
All sites – both areas 2009	34	408	23	54	78.7 (2.6)	41.2
Comparison between survey areas in 2009						
Mann-Whitney U Test Statistic					315.5	
p-value					0.657	
Comparison between years (GC 2004/2009)						
Mann-Whitney U Test Statistic					235.0	
p-value					0.696	

Table 2. Abalone counts (N) and density estimates by size category for index sites in Queen Charlotte Strait as well as Mann-Whitney test results between survey areas and survey years. Standard errors are shown in brackets. P-values in bold indicate significant difference ($p<0.05$).

	Immature (<70mm)		Mature (≥70mm)		Large (≥100mm)		Total
	N	Density	N	Density	N	Density	Density
Gordon Channel 2004	6	0.019 (0.016)	7	0.023 (0.010)	1	0.003 (0.003)	0.042 (0.020)
Gordon Channel 2009	14	0.057 (0.023)	25	0.106 (0.047)	8	0.035 (0.016)	0.164 (0.061)
North Queen Charlotte Strait 2009	5	0.018 (0.015)	10	0.037 (0.016)	2	0.007 (0.005)	0.055 (0.020)
All sites – both areas 2009	19	0.038 (0.014)	35	0.072 (0.025)	10	0.021 (0.009)	0.109 (0.033)
Comparison between survey areas in 2009							
Mann-Whitney U Test Statistic		179.0		160.0		174.0	164.0
p-value		0.110		0.520		0.150	0.451
Comparison between years (GC 2004/2009)							
Mann-Whitney U Test Statistic		121.0		136.5		120.5	127.5
p-value		0.078		0.331		**0.045**	0.199

Table 3. Dive survey summary for abalone and urchins by site, Queen Charlotte Strait, 2009. Standard errors are shown in brackets.

Site	Date	Bottom Time (min)	Depth (m) Min	Depth (m) Max	Number Of Quadrats	Abalone Count	Abalone Density (#/m^2)	Urchin Count	Urchin Density (#/m^2)
Gordon Channel									
I01	May 23	58	1	3	15	1	0.067	139	9.27
I02	May 23	37	0	3	16	0	0.000	96	6.00
I03	May 23	30	-2	1	8	0	0.000	38	4.75
I04	May 23	23	-1	1	8	0	0.000	24	3.00
I05	May 22	65	1	8	16	5	0.313	44	2.75
I06	May 22	38	1	5	16	0	0.000	3	0.19
R02	May 22	50	0	4	9	7	0.778	0	0.00
R03	May 23	72	-1	2	16	4	0.250	46	2.88
R04	May 22	26	-2	2	8	0	0.000	0	0.00
R06	May 22	59	1	4	16	8	0.500	18	1.13
R07	May 22	20	4	5	8	0	0.000	71	8.88
R10	May 23	20	0	4	8	0	0.000	55	6.88
R11	May 23	26	-1	1	8	0	0.000	22	2.75
R12	May 22	38	-1	-1	8	0	0.000	3	0.38
R15	May 22	50	-1	1	16	10	0.625	14	0.88
R19	May 22	32	1	6	16	4	0.250	5	0.31
R20	May 23	23	-2	3	8	0	0.000	86	10.75
					Totals	**39**	**0.164 (0.061)**	**664**	**3.58 (0.87)**
North Queen Charlotte Strait									
R28	May 24	29	-1	2	8	0	0.000	0	0.00
R29	May 24	55	1	6	16	3	0.188	71	4.44
R30	May 25	40	2	6	16	0	0.000	42	2.63
R31	May 24	50	-1	4	16	1	0.063	7	0.44
R33	May 25	43	0	7	16	4	0.250	129	8.06
R34	May 23	30	2	7	8	0	0.000	44	5.50
R35	May 24	55	1	5	16	2	0.125	60	3.75
R36	May 25	30	-1	4	16	0	0.000	84	5.25
R38	May 25	20	-1	3	8	0	0.000	1	0.13
R39	May 24	46	-1	5	16	3	0.188	102	6.38
R47	May 25	29	0	6	16	1	0.063	110	6.88
R48	May 24	25	0	3	8	0	0.000	26	3.25
R49	May 25	48	1	7	16	1	0.063	28	1.75
R51	May 24	25	0	3	8	0	0.000	0	0.00
R53	May 25	23	-1	0	8	0	0.000	0	0.00
R54	May 24	25	0	4	8	0	0.000	17	2.13
R57	May 25	15	-1	3	8	0	0.000	0	0.00
					Totals	**15**	**0.055 (0.020)**	**721**	**2.97 (0.66)**
					All Sites	**54**	**0.109 (0.033)**	**1385**	**3.27 (0.54)**

Table 4. Site descriptions of sites sampled in the Queen Charlotte Strait, May 2009. The most common substrate types are listed (1 = first, 2 = second, 3 = third) where substrate code 1 = bedrock (hard and/or smooth), 2 = hard, complex boulder, 3 = mainly cobble, 4 = mixed hard/soft with hard terminate, 5 = mainly soft. The percent cover (%) and dominant algal species (Sp 1 = most common and Sp 2 = second most common) are listed by growth characteristics where algae species codes AB = *Agarum clathratum* (formerly *A. cribrosum*), AC = articulated corallines, AF = *Agarum fimbriatum*, AL = *Alaria sp.*, AM = *A. marginata*, BF = brown foliose, CO = *Costaria costata*, CY = *Cymathere triplicata*, DL = *Desmarestia ligulata*, DM = *D. munda*, DV = *D. viridis*, EG = *Egregia menziesii*, IR = *Mazzaella* sp. (formerly *Iridaea* sp.), LB = *Laminaria bongardiana*, LS = *L. saccharina*, LT = *L. setchellii*, MA = *Macrocystis integrifolia*, NT = *Nereocystis luetkeana*, PL = *Pleurophycus gardneri*, PT = *Pterygophora californica*, RB = red branched, RF = red foliose, RH = red filamentous, UL = *Ulva sp.*

	Substrate			Slope	Canopy			Understorey			Turf			Encrusting
Site	1	2	3	%	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%	Sp 1	Sp 2	%
Gordon Channel														
I01	2	4	1	16	70	NT	EG	50	CY	CO	10	RB	UL	90
I02	1	4	2	21	40	NT		70	CY	DV	1	AC		90
I03	1			42	5	NT		80	AM	DL	5	RB		10
I04	5	2	4	27	10	NT		50	CY	CO	5	UL	AC	70
I05	1	2		38	90	NT		100	PT	DV	5	BF	AC	10
I06	1	5	4	27	80	NT		70	DV	CY	5	AC		50
R02	1			34	20	NT	PT	100	PT	LB	10	AC		10
R03	1	4		17	70	NT		100	CY	DM	40	RH	AC	50
R04	4	5	1	38	20	MA		100	DV	CY	25	AC	RB	30
R06	1			19	30	NT	PT	100	PT	LB	5	BF		10
R07	4	2	3	15	40	NT		50	AF	DV	5	AC		30
R10	1	2		46	25	NT		30	CY	DV	2	AC		95
R11	1	4		19	10	EG		80	AL	CY	10	AC		70
R12	2	4		11	10	MA	NT	100	CY	LB	10	AC		50
R15	2	1	4	13	40	NT		80	CY	DV	5	AC		70
R19	1	4	5	34	10	NT		40	AF	CO	0			40
R20	1			57	2	EG		10	DV	AL	5	AC		50
North Queen Charlotte Strait														
R28	1	4		38	30	NT		80	CY		80	UL	AC	30
R29	2	1	4	32	5	NT		70	LB	CY	5	BF		60
R30	1	2	4	29	70	PT	MA	0			5	RH	BF	50
R31	1	4	2	36	10	NT	EG	80	PL	PT	20	AL	RF	90
R33	1	2	4	40	5	NT		30	DM	DV	30	AC	RF	80
R34	1	2	4	57	30	NT		20	PL	LT	30	AC	IR	70
R35	2	1	4	30	25	NT		80	PT	CO	50	RH		95
R36	1	4	5	32	5	NT		10	AM	LB	20	UL	RB	80
R38	4	5	2	46	2	NT		80	AB		2	UL		2
R39	1	4	2	36	30	NT		70	LB	PL	30	AC	IR	80
R47	1	4	2	36	5	NT		10	DL	PT	10	RB	AC	90
R48	4	1		34	30	NT		80	AF	LS	10	AC		40
R49	4	2	1	38	5	NT		50	CO	NT	30	RH	BF	50
R51	2			38	0			100	AF	AB	0			20
R53	4	5		15	5	NT		80	LB	CO	40	RB	UL	10
R54	1	2		42	30	NT		50	AF	CO	10	UL	RB	90
R57	1	5	4	46	80	MA	PT	60	PT	LB	10	AC	BF	50

Table 5. Number of abalone found by dominant substrate type in the Queen Charlotte Strait, May 2009.

Dominant Substrate	Number of Sites	Percent of sites with abalone	Total Abalone count	Abalone per site
hard - bedrock	21	43	37	1.8
hard, complex boulder	6	67	16	2.7
mixed hard/soft	6	17	1	0.2

Table 6. Mean algae percent cover summarized by growth characteristics. Standard errors are shown in brackets. P-values in bold indicate significant difference ($p<0.05$).

	Canopy	Understorey	Turf	Encrusting
2004	14.2 (5.1)	55.0 (7.7)	38.7 (6.7)	76.3 (5.5)
2009	33.6 (6.8)	71.2 (6.9)	8.7 (2.4)	69.7 (6.3)
Comparison between years (GC 2004/2009)				
Mann-Whitney U Test Statistic	73.5	116.5	276.0	186.0
p-value	**0.005**	0.149	**0.000**	0.432

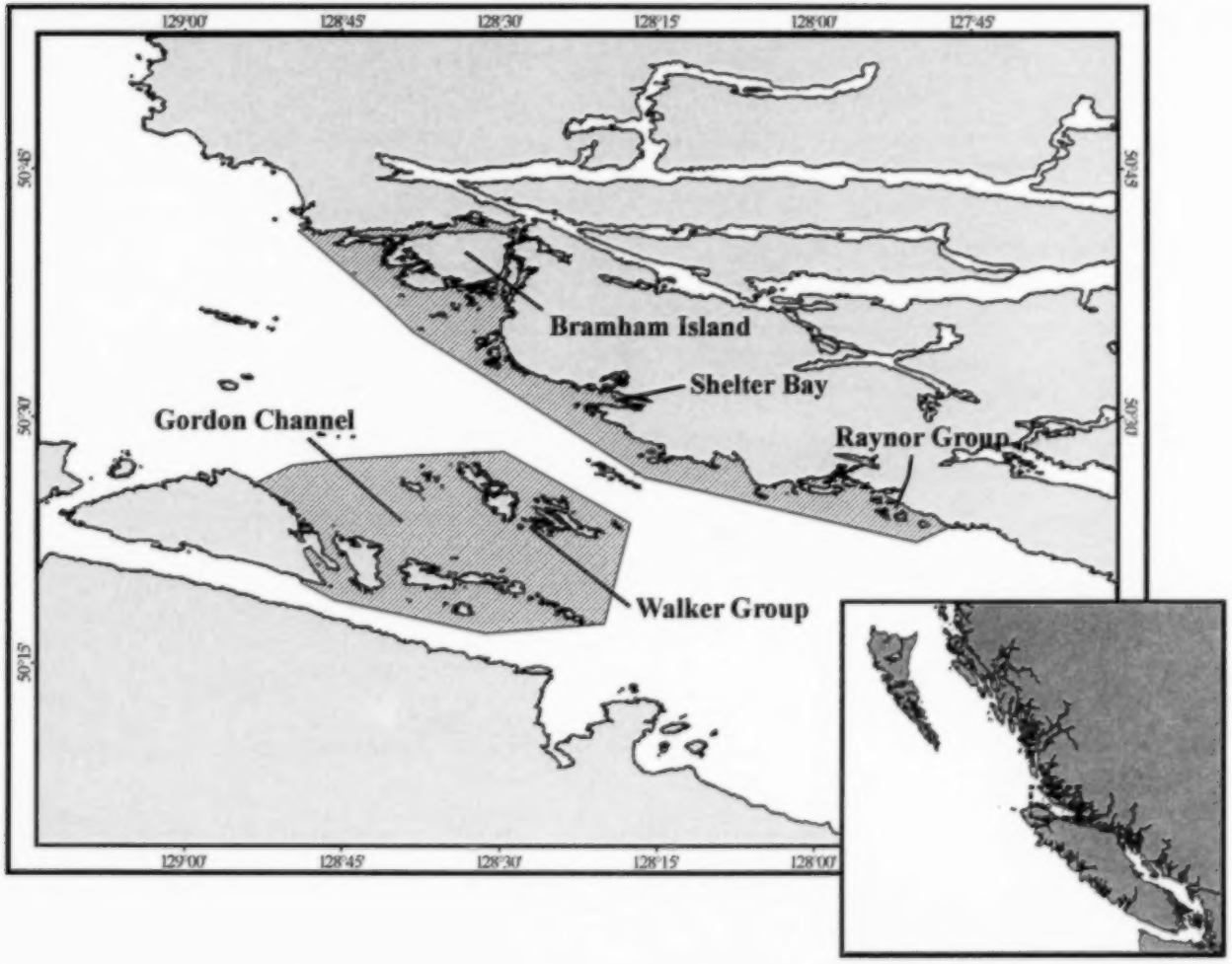

Figure 1. Map of Queen Charlotte Strait, showing the areas surveyed. Sites located on the northern side of QCS, including those around Bramham Island, Shelter Bay, and the Raynor Group, were named "North Queen Charlotte Strait" (NQCS) sites and those encompassing the Gordon Islands and Walker Group were named "Gordon Channel" (GC) sites.

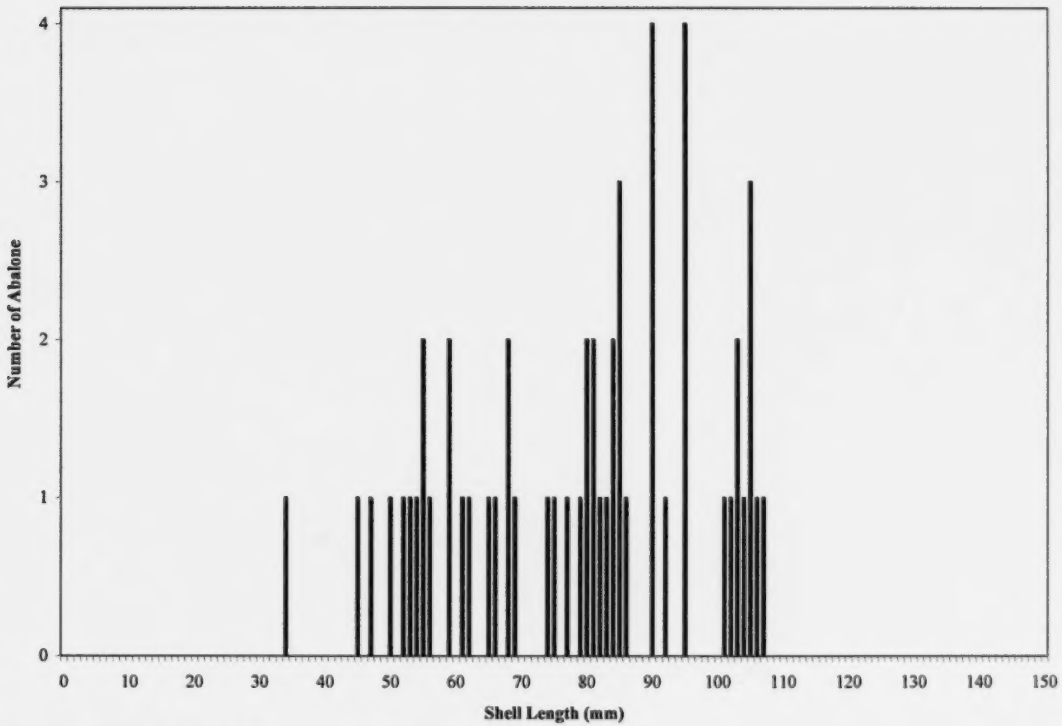

Figure 2. Size frequency distribution of abalone measured from all sites surveyed in Queen Charlotte Strait, May 2009.

Appendix 1. Density for exposed abalone by size category for each site surveyed in Queen Charlotte Strait, May 2009.

Site	Number of Quadrats	Total Number of Abalone	Density of Exposed Abalone by Size Category (mm)			
			<70	≥70	≥100	Total
Gordon Channel						
I01	15	1	0.000	**0.067**	**0.067**	**0.067**
I02	16	0	0.000	0.000	0.000	0.000
I03	8	0	0.000	0.000	0.000	0.000
I04	8	0	0.000	0.000	0.000	0.000
I05	16	5	**0.313**	0.000	0.000	**0.313**
I06	16	0	0.000	0.000	0.000	0.000
R02	9	7	**0.222**	**0.556**	**0.222**	**0.778**
R03	16	4	**0.125**	**0.125**	**0.063**	**0.250**
R04	8	0	0.000	0.000	0.000	0.000
R06	16	8	**0.063**	**0.438**	**0.125**	**0.500**
R07	8	0	0.000	0.000	0.000	0.000
R10	8	0	0.000	0.000	0.000	0.000
R11	8	0	0.000	0.000	0.000	0.000
R12	8	0	0.000	0.000	0.000	0.000
R15	16	10	**0.125**	**0.500**	**0.125**	**0.625**
R19	16	4	**0.125**	**0.125**	0.000	**0.250**
R20	8	0	0.000	0.000	0.000	0.000
North Queen Charlotte Strait						
R28	8	0	0.000	0.000	0.000	0.000
R29	16	3	0.000	**0.188**	**0.063**	**0.188**
R30	16	0	0.000	0.000	0.000	0.000
R31	16	1	**0.063**	0.000	0.000	**0.063**
R33	16	4	**0.250**	0.000	0.000	**0.250**
R34	8	0	0.000	0.000	0.000	0.000
R35	16	2	0.000	**0.125**	0.000	**0.125**
R36	16	0	0.000	0.000	0.000	0.000
R38	8	0	0.000	0.000	0.000	0.000
R39	16	3	0.000	**0.188**	0.000	**0.188**
R47	16	1	0.000	**0.063**	**0.063**	**0.063**
R48	8	0	0.000	0.000	0.000	0.000
R49	16	1	0.000	**0.063**	0.000	**0.063**
R51	8	0	0.000	0.000	0.000	0.000
R53	8	0	0.000	0.000	0.000	0.000
R54	8	0	0.000	0.000	0.000	0.000
R57	8	0	0.000	0.000	0.000	0.000